Attribution of Regional Radiative Forcing Due to Tropospheric Ozone: A Step Towards Climate Credit for Reductions in Emissions of O_3 Precursors

Vaishali Naik[1*], Denise Mauzerall[1,2], Larry Horowitz[3], Dan Schwarzkopf[3], V. Ramaswamy[3,2], and Michael Oppenheimer[1,2]

[1] Woodrow Wilson School of Public and International Affairs, Princeton University, Princeton, USA
[2]Department of Geosciences, Princeton University, Princeton, USA
[3]Geophysical Fluid Dynamics Laboratory, Princeton, USA
*vnaik@princeton.edu

1. Motivation

- Tropospheric ozone (O_3) is the **3rd most important greenhouse gas** after CO_2 and CH_4 with a mean forcing of **0.40 Wm^{-2}**
- O_3 is a **secondary pollutant** and its production depends non-linearly on the concentration of its short-lived precursors – **nitrogen oxide (NO_x), carbon monoxide (CO), and non-methane hydrocarbons (NMHCs)**, in addition to CH_4
- Attributing the **responsibility for radiative forcing due to O_3 to specific countries is not as straightforward** as it is for long-lived greenhouse gases, because it depends on the **location of precursor emissions** as well as on **where the O_3 is formed and transported**

2. Objectives

- Quantitatively estimate the reduction in radiative forcing from tropospheric O_3 attainable through potentially feasible reduction in the emissions of its precursors (NO_x alone and combined NO_x, CO, & NMHCs) from major regions of the world

3. Methodology

Tools: MOZART 3-D Chemical Transport Model to simulate global O_3 distribution and the GFDL Radiative Transfer Model to calculate O_3 radiative forcing

Approach: Simulate changes relative to 1990 base year in global O_3 distribution resulting from 10% reduction in surface anthropogenic

A. NO_x emissions from each of the 9 regions shown below

B. global NO_x emissions

C. combined NO_x, CO, & NMHCs emissions from EU, NA, and SE

D. combined global NO_x, CO, & NMHCs emissions

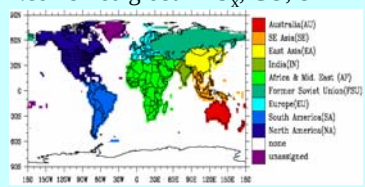
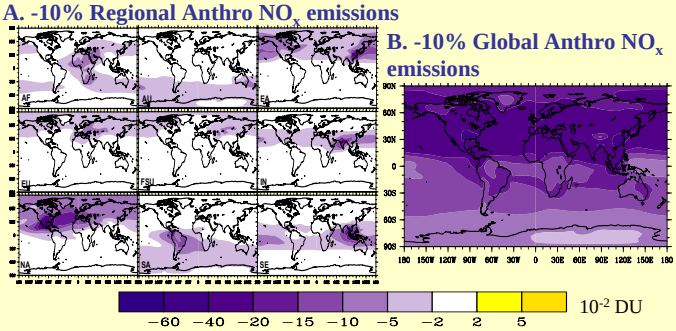


Fig1. Surface anthropogenic NO_x emissions were reduced by 10% from each of these regions of the world for simulation A.

4. Change in annual tropospheric O_3 column (perturbation-base)

A. -10% Regional Anthro NO_x emissions

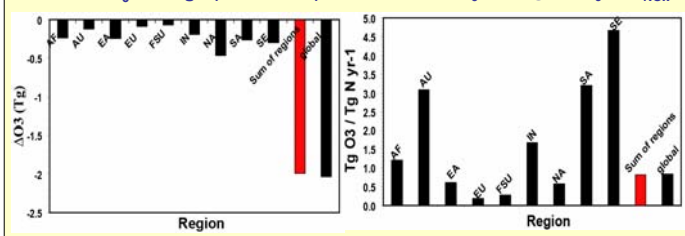
B. -10% Global Anthro NO_x emissions



- The largest O_3 column reductions occur locally near the source of the emissions
- The spatial distribution of O_3 column reduction from global 10% anthropogenic NO_x emission reductions is similar to the sum of individual regional column reductions

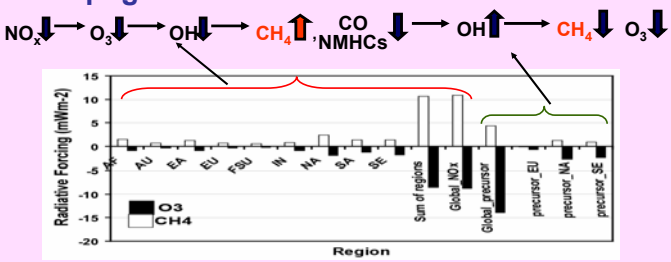
5. Change in annual global O_3 burden

Absolute O_3 Change (Pert–Base) **Normalized O_3 Change (ΔO_3 / ΔE_{NOx})**



- The global O_3 reduction from reduced NO_x emissions depends on the amount of NO_x reduced from a region and the location of the region - largest reduction from North America followed by Southeast Asia
- The sensitivity of global O_3 change to NO_x reductions is highest for low NO_x emitting regions (Southeast Asia, South America and Australia) and lowest for high NO_x emitting regions (Europe, the Former Soviet Union) with concentrated emissions
- The regional reductions in global O_3 burden are additive

6. Radiative forcing due to changes in O_3 and CH_4 resulting from a 10% reduction in surface anthropogenic emissions



- Changes in CH_4 and O_3 concentrations resulting from NO_x emission reductions produce radiative forcing changes that largely offset each other leaving a small residual forcing that is positive for all regions except SE and IN
- In contrast, for combined reductions of anthropogenic emissions of NOx, CO, and NMHCs, changes in O_3 and CH_4 concentrations result in a net reduction in the radiative forcing suggesting an overall cooling

7. Conclusions

- Ozone production and resulting distributions depend strongly on the location of NO_x emissions
  - O_3 changes are most sensitive to NO_x reductions from low-NO_x regions (SE, SA, IN, AU) and least sensitive to high NO_x regions (EU, FSU, NA)
- The net radiative forcing from only NO_x reductions due to changes in CH_4 and O_3 is **POSTIVE** for all regions except for SE and IN
- Combined reduction of anthropogenic emissions of all O_3 precursors yields a net **NEGATIVE** climate forcing
  - Therefore, a climate treaty seeking to obtain co-benefits from reduced radiative forcing and air pollution mitigation could find further examinations of credits for simultaneous reductions of regional emissions of NO_x, CO, and NMHCs worthwhile

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